Abutment verification

Input data

Project
Date: 29.10.2015

Settings
(input for current task)

Materials and standards
Abutment: EN 1992-1-1 (EC2)
Coefficients EN 1992-1-1: standard

Wall analysis
Active earth pressure calculation: Coulomb
Passive earth pressure calculation: Caquot-Kerisel
Earthquake analysis: Mononobe-Okabe
Shape of earth wedge: Calculate as skew
Allowable eccentricity: 0,333
Verification methodology: Safety factors (ASD)

<table>
<thead>
<tr>
<th>Safety factors</th>
<th>Permanent design situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety factor for overturning: SF_o</td>
<td>1,50 [-]</td>
</tr>
<tr>
<td>Safety factor for sliding resistance: SF_s</td>
<td>1,50 [-]</td>
</tr>
<tr>
<td>Safety factor for bearing capacity: SF_b</td>
<td>1,00 [-]</td>
</tr>
</tbody>
</table>

Geometry of structure

<table>
<thead>
<tr>
<th>No.</th>
<th>Coordinate X [m]</th>
<th>Depth Z [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0,00</td>
<td>1,50</td>
</tr>
<tr>
<td>2</td>
<td>0,00</td>
<td>2,50</td>
</tr>
<tr>
<td>3</td>
<td>-1,00</td>
<td>4,00</td>
</tr>
<tr>
<td>4</td>
<td>-1,00</td>
<td>8,50</td>
</tr>
<tr>
<td>5</td>
<td>1,00</td>
<td>8,90</td>
</tr>
<tr>
<td>6</td>
<td>1,00</td>
<td>9,90</td>
</tr>
<tr>
<td>7</td>
<td>-3,80</td>
<td>9,90</td>
</tr>
<tr>
<td>8</td>
<td>-3,80</td>
<td>8,90</td>
</tr>
<tr>
<td>9</td>
<td>-1,80</td>
<td>8,50</td>
</tr>
<tr>
<td>10</td>
<td>-1,80</td>
<td>1,50</td>
</tr>
<tr>
<td>11</td>
<td>-0,80</td>
<td>1,50</td>
</tr>
</tbody>
</table>

The origin [0,0] is located at the most upper right point of the wall. Wall section area = 13,27 m².

Length of bridge abutment = 5,00 m
Length of abutment foundation = 5,40 m
Abutment wingwalls - hinged symmetric

Wingwall thickness = 0.40 m
Length of wingwall behind closure wall = 4.00 m
Wingwall height = 4.00 m
Dist. of wingwall cut from c.w. = 2.00 m
Depth of wingwall cut = 4.00 m

Material of structure

Unit weight $\gamma = 23.00$ kN/m$^3$
Analysis of concrete structures carried out according to the standard EN 1992-1-1 (EC2).

Concrete: C 20/25
Cylinder compressive strength $f_{ck} = 20.00$ MPa
Tensile strength $f_{ctm} = 2.20$ MPa
Longitudinal steel: B500
Yield strength $f_{yk} = 500.00$ MPa

Soil parameters

**Soil No. 1**
Unit weight: $\gamma = 19.00$ kN/m$^3$
Stress-state: effective
Angle of internal friction: $\varphi_{ef} = 29.00^\circ$
Cohesion of soil: $c_{ef} = 8.00$ kPa
Angle of friction struc.-soil: $\delta = 15.00^\circ$
Soil: cohesionless
Saturated unit weight: $\gamma_{sat} = 19.00$ kN/m$^3$

**Soil No. 2**
Unit weight: $\gamma = 19.00$ kN/m$^3$
Stress-state: effective
Angle of internal friction: $\varphi_{ef} = 29.00^\circ$
Cohesion of soil: $c_{ef} = 8.00$ kPa
Angle of friction struc.-soil: \( \delta = 15,00 \, ^\circ \)
Saturated unit weight: \( \gamma_{sat} = 19,00 \, kN/m^3 \)

**Soil No. 3**
Unit weight: \( \gamma = 19,00 \, kN/m^3 \)
Stress-state: effective
Angle of internal friction: \( \phi_{ef} = 29,00 \, ^\circ \)
Cohesion of soil: \( c_{ef} = 8,00 \, kPa \)
Saturated unit weight: \( \gamma_{sat} = 19,00 \, kN/m^3 \)

**Soil No. 4**
Unit weight: \( \gamma = 19,00 \, kN/m^3 \)
Stress-state: effective
Angle of internal friction: \( \phi_{ef} = 29,00 \, ^\circ \)
Cohesion of soil: \( c_{ef} = 8,00 \, kPa \)
Saturated unit weight: \( \gamma_{sat} = 19,00 \, kN/m^3 \)

Load case, bridge load
Type of load case: construction state.

**Geological profile and assigned soils**

<table>
<thead>
<tr>
<th>No.</th>
<th>Layer [m]</th>
<th>Assigned soil</th>
<th>Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3,00</td>
<td>Soil No. 1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3,00</td>
<td>Soil No. 2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3,00</td>
<td>Soil No. 3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>Soil No. 4</td>
<td></td>
</tr>
</tbody>
</table>

**Foundation**
Type of foundation: soil from geological profile

**Terrain profile**
Terrain behind construction has the slope 1: 5,00 (slope angle is 11,31 \(^\circ\)). Embankment height is 1,00 m, embankment length is 5,00 m.

**Water influence**
Ground water table is located below the structure.

**Resistance on front face of the structure**
Resistance on front face of the structure is not considered.

**Settings of the stage of construction**
Design situation: permanent
The wall is free to move. Active earth pressure is therefore assumed.
Verification No. 1 (Stage of construction 1)

Forces acting on construction

<table>
<thead>
<tr>
<th>Name</th>
<th>$F_{\text{hor}}$ [kN/m]</th>
<th>App.Pt. z [m]</th>
<th>$F_{\text{vert}}$ [kN/m]</th>
<th>App.Pt. x [m]</th>
<th>Design coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight - wall</td>
<td>0,00</td>
<td>-3,33</td>
<td>305,21</td>
<td>2,51</td>
<td>1,000</td>
</tr>
<tr>
<td>Weight - earth wedge</td>
<td>0,00</td>
<td>-2,51</td>
<td>59,38</td>
<td>3,47</td>
<td>1,000</td>
</tr>
<tr>
<td>Active pressure</td>
<td>172,56</td>
<td>-2,43</td>
<td>195,45</td>
<td>3,96</td>
<td>1,000</td>
</tr>
</tbody>
</table>

Abutment check
Verification for slip has not been performed.

Check for overturning stability
Resisting moment $M_{\text{res}} = 1615,54$ kNm/m
Overturning moment $M_{\text{ovr}} = 388,16$ kNm/m

Safety factor = 4,16 > 1,50
Wall for overturning is SATISFACTORY

Overall check - ABUTMENT is SATISFACTORY

Bearing capacity of foundation soil (Stage of construction 1)

Design load acting at the center of footing bottom

<table>
<thead>
<tr>
<th>No.</th>
<th>Moment [kNm/m]</th>
<th>Norm. force [kN/m]</th>
<th>Shear Force [kN/m]</th>
<th>Eccentricity [-]</th>
<th>Stress [kPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17,14</td>
<td>518,55</td>
<td>159,77</td>
<td>0,007</td>
<td>109,54</td>
</tr>
</tbody>
</table>

Service load acting at the center of footing bottom
Verification of foundation soil

Eccentricity verification
Max. eccentricity of normal force $e = 0.007$
Maximum allowable eccentricity $e_{alw} = 0.333$

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity
Max. stress at footing bottom $\sigma = 109.54$ kPa
Bearing capacity of foundation soil $R_d = 240.00$ kPa
Safety factor $= 2.19 > 1.00$
Bearing capacity of foundation soil is SATISFACTORY

Overall verification - bearing capacity of found. soil is SATISFACTORY

Dimensioning No. 1 (Stage of construction 1)

Forces acting on construction

<table>
<thead>
<tr>
<th>Name</th>
<th>$F_{\text{hor}}$ [kN/m]</th>
<th>App.Pt. z [m]</th>
<th>$F_{\text{vert}}$ [kN/m]</th>
<th>App.Pt. x [m]</th>
<th>Design coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight - wall</td>
<td>0.00</td>
<td>-4.11</td>
<td>169.05</td>
<td>0.60</td>
<td>1.00</td>
</tr>
<tr>
<td>Active pressure</td>
<td>87.83</td>
<td>-1.76</td>
<td>23.54</td>
<td>0.80</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Dimensioning of abutment stem - input data:
Construction joint is designed from steel-reinforced concrete; design width 1m.

Bar diameter = 25.0 mm
Number of bars = 12
Reinforcement cover = 30,0 mm

Internal forces: \( M = 112,19 \text{ kNm/m}; N = -192,58 \text{ kN/m}; V = 87,83 \text{ kN/m} \)
Cross-section depth \( h = 0,80 \text{ m} \)

**Dimensioning of abutment stem - results:**

<table>
<thead>
<tr>
<th>Reinforcement ratio ( \rho )</th>
<th>0.74 %</th>
<th>&gt; 0.13 %</th>
<th>( \rho_{\text{min}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position of neutral axis ( x )</td>
<td>0.50 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultimate shear force ( V_{\text{Rd}} )</td>
<td>366,18 kN/m</td>
<td>&gt; 87,83 kN/m</td>
<td>( V_{\text{Ed}} )</td>
</tr>
<tr>
<td>Ultimate compressive force ( N_{\text{Rd}} )</td>
<td>3152,34 kN/m</td>
<td>&gt; 192,58 kN/m</td>
<td>( N_{\text{Ed}} )</td>
</tr>
<tr>
<td>Ultimate moment ( M_{\text{Rd}} )</td>
<td>1836,48 kNm/m</td>
<td>&gt; 112,19 kNm/m</td>
<td>( M_{\text{Ed}} )</td>
</tr>
</tbody>
</table>

Cross-section is SATISFACTORY.

### Input data (Stage of construction 2)

**Load case, bridge load**

Type of load case: service state.

**Forces generated by bridge**

- Vertical force \( F_{\text{b}} = 2000,00 \text{ kN} \)
- Horizontal force \( F_{\text{v}} = 0,00 \text{ kN} \)
- Location \( a_1 = 0,30 \text{ m} \)
- Depth \( v = 0,10 \text{ m} \)

**Forces due to transition slab**

- Vertical force \( F_{\text{b}} = 120,00 \text{ kN} \)
- Horizontal force \( F_{\text{v}} = -50,00 \text{ kN} \)
- Location \( a_2 = 0,20 \text{ m} \)
Geological profile and assigned soils

<table>
<thead>
<tr>
<th>No.</th>
<th>Layer [m]</th>
<th>Assigned soil</th>
<th>Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3,00</td>
<td>Soil No. 1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3,00</td>
<td>Soil No. 2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3,00</td>
<td>Soil No. 3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>Soil No. 4</td>
<td></td>
</tr>
</tbody>
</table>

Foundation
Type of foundation: soil from geological profile

Terrain profile
Terrain behind construction has the slope 1: 5,00 (slope angle is 11,31°). Embankment height is 1,00 m, embankment length is 5,00 m.

Water influence
Ground water table is located below the structure.

Resistance on front face of the structure
Resistance on front face of the structure is not considered.

Settings of the stage of construction
Design situation: permanent
The wall is free to move. Active earth pressure is therefore assumed.

Verification No. 1 (Stage of construction 2)

Forces acting on construction

<table>
<thead>
<tr>
<th>Name</th>
<th>$F_{\text{hor}}$ [kN/m]</th>
<th>$F_{\text{vert}}$ [kN/m]</th>
<th>Design coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight - wall</td>
<td>0,00</td>
<td>332,81</td>
<td>1,000</td>
</tr>
<tr>
<td>Weight - earth wedge</td>
<td>0,00</td>
<td>59,38</td>
<td>1,000</td>
</tr>
<tr>
<td>Active pressure</td>
<td>224,88</td>
<td>249,09</td>
<td>1,000</td>
</tr>
<tr>
<td>Abutment wingwalls</td>
<td>0,00</td>
<td>54,28</td>
<td>1,000</td>
</tr>
<tr>
<td>Bridge reactions</td>
<td>0,00</td>
<td>400,00</td>
<td>1,000</td>
</tr>
<tr>
<td>Appr. plate react.</td>
<td>10,00</td>
<td>24,00</td>
<td>1,000</td>
</tr>
</tbody>
</table>

Abutment check
Verification for slip has not been performed.

Check for overturning stability
Resisting moment $M_{\text{res}} = 3099,22$ kNm/m
Overturning moment $M_{\text{ovr}} = 644,78$ kNm/m
Safety factor = 4,81 > 1,50
Wall for overturning is SATISFACTORY

Overall check - ABUTMENT is SATISFACTORY
Bearing capacity of foundation soil (Stage of construction 2)

Design load acting at the center of footing bottom

<table>
<thead>
<tr>
<th>No.</th>
<th>Moment [kNm/m]</th>
<th>Norm. force [kN/m]</th>
<th>Shear Force [kN/m]</th>
<th>Eccentricity [-]</th>
<th>Stress [kPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33,47</td>
<td>1036,62</td>
<td>217,48</td>
<td>0,007</td>
<td>218,91</td>
</tr>
</tbody>
</table>

Service load acting at the center of footing bottom

<table>
<thead>
<tr>
<th>No.</th>
<th>Moment [kNm/m]</th>
<th>Norm. force [kN/m]</th>
<th>Shear Force [kN/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33,47</td>
<td>1036,62</td>
<td>217,48</td>
</tr>
</tbody>
</table>

Verification of foundation soil

Eccentricity verification
Max. eccentricity of normal force $e = 0,007$
Maximum allowable eccentricity $e_{alw} = 0,333$

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity
Max. stress at footing bottom $\sigma = 218,91$ kPa
Bearing capacity of foundation soil $R_d = 240,00$ kPa

Safety factor = $1,10 > 1,00$
Bearing capacity of foundation soil is SATISFACTORY

Overall verification - bearing capacity of found. soil is SATISFACTORY

Dimensioning No. 1 (Stage of construction 2)

Forces acting on construction

<table>
<thead>
<tr>
<th>Name</th>
<th>$F_{\text{hor}}$ [kN/m]</th>
<th>App.Pt. $z$ [m]</th>
<th>$F_{\text{vert}}$ [kN/m]</th>
<th>App.Pt. $x$ [m]</th>
<th>Design coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight - wall</td>
<td>0,00</td>
<td>-4,62</td>
<td>196,65</td>
<td>0,71</td>
<td>1,000</td>
</tr>
<tr>
<td>Active pressure</td>
<td>128,68</td>
<td>-2,07</td>
<td>34,48</td>
<td>0,83</td>
<td>1,000</td>
</tr>
<tr>
<td>Abutment wingwalls</td>
<td>0,00</td>
<td>-6,60</td>
<td>54,28</td>
<td>3,50</td>
<td>1,000</td>
</tr>
<tr>
<td>Bridge reactions</td>
<td>0,00</td>
<td>-7,10</td>
<td>400,00</td>
<td>0,30</td>
<td>1,000</td>
</tr>
<tr>
<td>App. plate react.</td>
<td>10,00</td>
<td>-8,50</td>
<td>24,00</td>
<td>1,60</td>
<td>1,000</td>
</tr>
</tbody>
</table>

Dimensioning of abutment stem - input data:

Construction joint is designed from steel-reinforced concrete; design width 1m.

Bar diameter $= 25,0$ mm
Number of bars $= 12$
Reinforcement cover $= 30,0$ mm

Internal forces: $M = 118,41$ kNm/m; $N = -709,41$ kNm/m; $V = 138,68$ kNm/m
Cross-section depth $h = 0,80$ m

Dimensioning of abutment stem - results:

Reinforcement ratio $\rho = 0,74\% > 0,13\% = \rho_{\text{min}}$
Position of neutral axis $x = 0,67$ m
Ultimate shear force $V_{Rd} = 443,70$ kNm/m $> 138,68$ kNm/m $= V_{\text{Ed}}$
Ultimate compressive force $N_{Rd} = 6692,26$ kNm/m $> 709,41$ kNm/m $= N_{\text{Ed}}$
Ultimate moment $M_{Rd} = 1116,99$ kNm/m $> 118,41$ kNm/m $= M_{\text{Ed}}$

Cross-section is SATISFACTORY.